Rejecting broadcast station interference

Is broadcast interference causing you problems on your software defined receiver (SDR)? Attack it with this simple preselector you can build yourself.

PHOTO 1: Inside one of the prototype filters. This differs from Figure 4 in that it has a switch to select between two different inductors (one on the white former, the other on a smaller toroid to the left).

Amateur radio receivers are pretty sensitive these days. Broadcast (BC) signals are often very, very strong and from time to time cause us radio amateurs problems. The trend towards direct conversion, zero IF, software defined radios (SDR) has brought broadcast station interference (BCI) back to our attention. This article describes how you can construct for yourself a simple preselector to eliminate most of the most common forms of BCI. None of the following is new but it is hoped it will give an insight into simple tuned circuit theory and show how a filter you can build yourself can help you attack the problem.

What does BCI sound like? If, when you listen to the amateur bands, you can hear superimposed on the amateur band an amplitude modulated (AM) broadcast signal and this signal does not tune but is present whatever frequency you tune to, then you certainly have BCI. Even some of the most sophisticated modern transceivers and especially those using SDR technology seem to be susceptible to a greater or lesser degree. The interfering AM signal appears when the sheer strength of the broadcast station signal overwhelms the front end filters and the analogue to digital converter or mixer. Some of such interference comes from medium wave AM stations and many receivers include a high pass filter in the front end to attenuate such signals.

In my case, in the evenings, a low level AM signal appeared all over 15m (and at times on 30, 20 and 17m as well). By connecting my antenna to a spectrum analyser I was able to see that very strong AM signals appeared in the 25 and 22m broadcast bands. At times these signals peaked at -12dBm, or about 60dB over S9! Radio China on 13.7MHz seemed to be the main culprit but I also had a case that sounded like some sort of digital signal. Now you may think that the front end filters in the receiver will suppress such a signal but these filters are often rather more broadband than you might hope in order to cater for the general coverage user or because of commercial constraints.

So how might this type of problem be tackled? The first action is to reduce the receiver radio frequency (RF) amplification so that the antenna noise just overrides the receiver noise. Indeed in my case this did reduce the problem somewhat. But amateur radio is about copying weak signals and quite often one needs to use the full amplification available to be able to copy signals easily, especially if band noise is low. What is really needed is better RF selectivity in the receiver front end.

There are two approaches, either to attenuate the offending signal specifically using a bandstop filter tuned to its frequency, or by selecting the wanted amateur band signal with a bandpass filter. As, potentially at least, BCI could arise from signals in any of the 41, 31, 25, 22, 19 or even 16m broadcast bands then the latter approach, bandpass filtering, is likely to be more effective. This is the basis of the so called 'preselector' that, as its name implies, pre-selects a band of frequencies by being placed between the receiver input and the antenna. It only allows a relatively narrow set of frequencies to pass through, ideally rejecting all frequencies higher and lower than the wanted (centre) frequency. The short wave listener (SWL) community often makes use of preselectors to winkle out weaker stations.

A practical preselector will pass frequencies in the selected (eg amateur) band and attenuate other frequencies in any adjacent broadcast bands. Two simple inductor (L)-capacitor (C) circuits do this, the parallel LC and the series LC circuit. Here I am going to analyse the latter but the arguments also apply to the parallel circuit.

Frequency selection is determined by the width of the passband needed to cover an amateur band. For example we would want to pass all of the 450kHz of the 21MHz band

with less than 3dB attenuation. The Q [1] of the filter should be approximately 21/0.45 = 47. A simple LC filter with this characteristic would attenuate 13.7MHz by over 20dB.

Now let's take a look at how a typical series circuit connected between antenna and receiver (as shown in **Figure 1**) might perform. I am indebted to VK6APH for his very clear explanation, which you can find at [2]. A simple series LC circuit resonating at 21MHz could be an inductance of 1μH in series with a capacitor of 57pF. The Q of this combination on its own might well be close to 200, which would have 3dB bandwidth of 21/200 = 100kHz, apparently easily selective enough for our purpose. But what happens when we insert this filter between the antenna and the receiver, as shown in **Figure 2**? If we actually *measure* the bandwidth, it is more like 16MHz! It seems that the circuit has suddenly become very broad – not quite what we intended! This change arises because we have omitted to include the impedances of the source (the antenna) and the load (the receiver) in the bandwidth calculation. Say, for example, that these are each 50Ω (and the inductor itself has a negligible resistance), as shown in Figure 2. Q is calculated from the frequency (expressed in radians per second, or 2 x π x frequency in cycles per second) times the inductance, divided by the *total* resistance. Using the values shown in Figure 2 and a frequency of 21MHz,

Q = ωL/R
= 2 x π x 21MHz x 0.1μH x / (50Ω + 50Ω)
= 1.32

From this we can calculate the 3dB bandwidth as 21/1.32, about 16MHz. *[More details about the maths employed here can be found at [1], [2] and most basic electronics textbooks – Ed].*

So how might we change the circuit to make it more effective? The answer is to reduce the resistive part of the circuit. We can step the input signal down from 50Ω in a broadband transformer to, say, 5Ω, then pass the signal through the LC filter, then step it back up to 50Ω in another broadband transformer, as shown in **Figure 3**. Then the calculation becomes

Q = ωL/R
= 2 x π x 21MHz x 1μH x (5Ω + 5Ω)
= 13.2

and the 3dB bandwidth is 21/15, or a much more satisfactory 1.6MHz.

This forms the basis of a simple, practical circuit to use between the antenna and receiver. To cover several amateur bands the capacitor needs to be variable. The inductance should be capable of being switched to give a number of selectable values if the circuit is intended to cover both LF and HF. For most receiver applications insertion loss is not too important as there is usually plenty of gain available.

On the basis of my calculation a series of prototype filters were constructed. The 3:1 and 1:3 transformers were constructed according

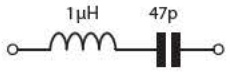

FIGURE 1: Series tuned circuit.

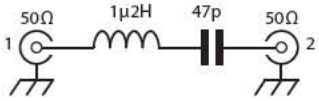

FIGURE 2: Series LC between antenna and receiver.

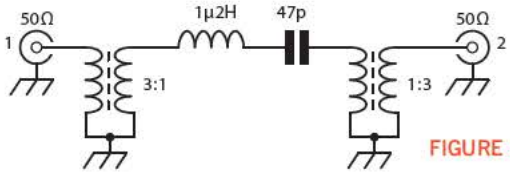

FIGURE 3: Basis of final circuit.

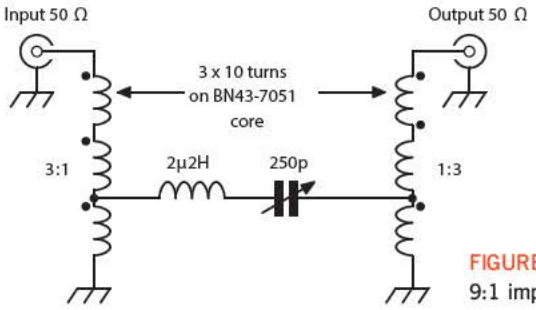

FIGURE 4: Final basic circuit including 9:1 impedance transformers.

to the circuit of **Figure 4** – note that the dots by the transformer indicate the start of each winding: it's important to connect them the right way round. The transformers were 10 trifilar turns on a ferrite toroid of permeability μ = 125. The transformers are connected to give a 3:1 step down/up and thus a 9:1 impedance ratio, 50Ω to 5.5Ω. The variable capacitor was small air spaced variable of about 250pF maximum. A number of inductors, toroidal and air cored, were wound in the ranges 1 to 3μH. Broadly, the trend is that as the L to C ratio increases so the Q and insertion loss increase.

A design with a simple air cored coil (10 turns on 25mm diameter, length 10mm, giving an inductance of about 2.2μH) tuned to 21MHz has an insertion loss of about 1.4dB and a 3dB bandwidth of about 800kHz. 13.7MHz is 28dB down. Inserting this circuit between the antenna and the receiver and peaking it at 21MHz completely removed all traces of BC AM interference. The full range of tuning was from 7 to 24MHz. However, across the range the selectivity does vary, for example at 14MHz the bandwidth is similar but the loss is 0.6dB. Using a smaller coil of about 0.8μH gave an insertion loss of <1dB at 21MHz but still attenuated 13.7MHz by ~20dB. A coil of 15 turns on a T106 yellow toroid (L ~ 2.5μH) gave, at 14MHz, a loss of < 1dB and a bandwidth of 600kHz; it had a similar bandwidth at 21MHz but an increased loss of ~1.7dB. These are given as examples since a degree of experimentation will be needed and the actual values of bandwidth and insertion loss will vary a bit with the components used, aerial / radio impedance and so on.

Photo 1 shows the air cored coil prototype in a screened box. Commercially, preselectors of this type are used in the Hilberling high end transceiver and a rather fine computer-controlled version is available from HEROS Technology [3]. For amateur use it is quite satisfactory to tune the capacitor manually to peak the noise on receive. Old timers will recall that it was normal to have a peaking control to tune the receiver front end. Such a filter as described here inserted between the antenna and receiver input and tuned to any of the HF bands completely removed all traces of BC AM interference.

Since I used good-sized components and the insertion loss is pretty low, I can also transmit *low* power through mine. If you use miniature components and / or higher powers than a watt or two then you will need to arrange a relay to bypass the preselector if you want to use it in conjunction with a transmitter.

Websearch

[1] Q, or 'Q factor' is a dimensionless parameter that describes how under damped or lossy a resonating circuit is a sort of 'goodness factor'. For more info see https://en.wikipedia.org/wiki/Q factor
[2] http://tinyurl.com/l8s8nup or http://openhpsdr.org/wiki/index.php?title ANICETUS
[3] http://tinyurl.com/kcy5dry or http://herostechnology.co.uk/pages/tiny SCR preselector.html

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